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ORIGINAL RESEARCH

THE DIAGNOSTIC ACCURACY OF THE LEVER SIGN FOR DETECTING ANTERIOR CRUCIATE LIGAMENT INJURY

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ABSTRACT

Background: An alternative physical examination procedure for evaluating the integrity of the anterior cruciate ligament (ACL) has been proposed in the literature but has not been validated in a broad population of patients with a symptomatic complaint of knee pain for its diagnostic value.

Purpose: To investigate the diagnostic accuracy of the Lever Sign to detect ACL tears and compare the results to Lachman testing in both supine and prone positions.

Study design: Prospective, blinded, diagnostic accuracy study.

Methods: Sixty-two consecutive patients with a complaint of knee pain were independently evaluated for the status of the ACL's integrity with the Lever Sign and the Lachman test in a prone and supine by a blinded examiner before any other diagnostic assessments were completed.

Results: Twenty-four of the 60 patients included in the analysis had a torn ACL resulting in a prevalence of 40%. The sensitivity of the Lever Sign, prone, and supine Lachman tests were 38, 83, and 67 % respectively and the specificity was 72, 89, and 97% resulting in positive likelihood ratios of 1.4, 7.5, and 24 and negative likelihood ratios of 0.86, 0.19, and 0.34 respectively. The positive predictive values were 47, 83, and 94% and the negative predictive values were 63, 89, and 81% respectively. The diagnostic odds ratios were 1.6, 40, and 70 with a number needed to diagnose of 10.3, 1.4, and 1.6 respectively.

Conclusions: The results of this study suggest that Lever Sign, in isolation, does not accurately detect the status of the ACL. During the clinical examination, the Lever Sign should be used as an adjunct to the gold standard assessment technique of anterior tibial translation assessment as employed in the Lachman tests in either prone or supine position.

Level of Evidence: 2

Key Terms: Anterior cruciate ligament, diagnosis, knee, Lachman test, Lever Sign, sensitivity, specificity

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We declare that we have no conflicts of interest in the authorship or publication of this contribution.

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INTRODUCTION

Physical examination of patients with knee injuries frequently involves assessment of ligamentous stability. One of the most common ligamentous injuries of the knee is to the anterior cruciate ligament (ACL). Early recognition is crucial in dictating the course of care to optimize outcomes. A variety of examination techniques have been proposed to detect this injury including the Lachman, Anterior Drawer, and Pivot Shift tests. Of these tests, the Lachman test is considered the clinical gold standard for diagnosing this injury because of its well-established sensitivity, specificity, likelihood ratios, and ease of application for patients of any size.[1-5] The accuracy of this test is enhanced with an appreciation for the anterior tibial translation endpoint quality in addition to the interpreting the magnitude of the translational asymmetry between limbs.[5]

Recently, a new test has been proposed that is equally easy to perform and may be a more convenient assessment for the patient when trying to identify both partial and full tears of the ACL.[6] The Lever Sign is a manual examination technique in which a posteriorly directed force is applied to the femur with a fulcrum placed under the posterior tibia to assess whether or not this force causes the distal end of the lever (heel) to rise from the support surface. A negative test occurs when an intact ACL allows the examiner's fist to serve as the fulcrum for a downward levering force on the distal femur. This force should easily overcome the force of gravity and allow the knee to rotate and heel to elevate from the support surface. A positive test is present when the downward force does not cause the heel to rise from the support surface. Lelli A et al retrospectively performed the Lever Sign on both limbs of 400 subjects with unilateral, acute or chronic, and complete or partial tears of the ACL after confirmation based on magnetic resonance imaging (MRI). For the 400 involved subjects, they found perfect sensitivity and specificity using the asymptomatic knee as a true negative control.[6] In contrast to the findings based on the Lever Sign results, only the subgroup of subject with chronic, complete tears had similar diagnostic accuracy as interpreted by the Lachman, Anterior Drawer, and Pivot Shift tests.[6]

Recently investigators evaluated the arthroscopic and radiologic correlation of the Lever Sign findings to detect ACL injury when the subject was pre-anesthesia and under anesthesia.[7] These investigators found nearly perfect sensitivity (94, 98%) in pre-anesthesia and under-anesthesia conditions, respectively. The Lachman, Pivot Shift and Anterior Drawer tests demonstrated slightly less sensitivity under anesthesia (all at 88%) with much lower sensitivity during the pre-anesthesia assessment at 80, 62, and 60% respectively. These authors did not reflect on the Lever Sign's specificity as all subjects had confirmed tears of the ACL and the evaluations were performed at the time of surgery.

Previous findings from these studies may have been prone to selection bias as the index test was applied to subjects with a known ACL tear. The current study aims to report the diagnostic accuracy of this examination technique in a more general population of patients presenting for evaluation of a complaint of knee pain. The purpose of this study was to evaluate the diagnostic accuracy of the Lever Sign to detect ACL tears and compare the results to Lachman testing in both supine and prone positions.

METHODS

The accuracy of the Lever Sign was assessed on consecutive subjects referred from the emergency department of a county teaching hospital to an orthopedic surgery specialty service for definitive evaluation of a painful knee. The subjects were between the ages of 18 and 65 with a complaint of knee pain rated as less than 7/10 on a verbal numerical rating scale. Subjects possessing at least 20-120° range of motion were eligible for inclusion. The study was approved by the institutional review boards at the University of Texas Southwestern Medical Center and Parkland Health and Hospital System in Dallas, TX. All subjects agreed via informed consent to participate in the investigation. Study exclusion criteria included: the suspicion of fracture based on the Ottawa knee rules,[8] previous knee joint arthroplasty, suspicion of posterior cruciate ligament (PCL) involvement, knee surgery in the previous six months, or the presence of serious underlying non-mechanical pathology or systemic illness.

The examination was conducted by a licensed physical therapist with 36 years of sports physical therapy experience. This examination was performed before

any other diagnostic evaluation was conducted, including injury history interview or review of previously conducted radiographic or magnetic resonance (MR) images. Therefore, the examiner had minimal knowledge regarding the subject's current condition and complaint.

After enrollment, each subject independently ambulated to the examination room without an assistive device to satisfy one of the items included in the Ottawa knee fracture rules. Active knee flexion to at least 90˚ and palpation for reproduction of pain complaint was conducted at the patella and fibular head to complete the Ottawa knee rule algorithm. If there were no adverse responses according to the knee rule, the examiners proceeded to screening for PCL injury. PCL injury evaluation was conducted via visual and palpatory assessment of a tibial sag sign with knee flexed at 90˚. If the tibial plateau did not appear to be at least 1 cm anterior to the femoral condyle, a quadriceps active drawer test was applied to rule in posterior cruciate ligament (PCL) injury. The palpatory loss of the tibia-femur step-off relationship has been shown to be a sensitive (0.90) and specific (0.99) means by which to detect the presence of a PCL injury.[9] The quadriceps active drawer test is performed by the subject gently contracting the quadriceps with the knee flexed at 90˚ and foot stabilized on the treatment plinth. The posterior displacement of the tibia will be reduced with this isometric contraction in the presence of a PCL tear. The specificity of this maneuver has been reported to be 96% and the sensitivity 53%.[9-10] All preliminary exclusion tests were performed by the same examiner who conducted the ACL stability assessment tests.

Following screening to rule on PCL involvement, the examiner assessed the subject for their ACL status by performing the Lever Sign and Lachman tests in the supine position followed by repeating the Lachman test in a prone position. The order in which these tests were conducted was randomized and the results of one examination technique were not allowed to alter the previously recorded results of another assessment maneuver. At the conclusion of the manual examinations, each subject was evaluated with the KT-1000™ arthrometer to record the millimeters of anterior translation at 15, 20, and 30 pounds (6.8, 9.1, and 13.6 kg) of force by a single examiner (EPM). The KT-1000™ is a mechanical joint arthrometer that allows for stabilization of the femur with concurrent instrumented assessment of the amount tibial translation when an anterior displacement force is applied to the proximal end of the lower leg and provides an objective, numerical result. This device has been shown to be an accurate and appropriate gauge of sagittal plane tibial displacement in a research setting.[11] Previous studies have shown that the examiner involved in the current study has demonstrated good reliability in performing the KT-1000™ examination with an intraclass correlation coefficient (3,1) of .90, .82, .88, and .78 at 15 pounds (6.8 kg), 20 pounds (9.1 kg), 30 pounds (13.6 kg), and at a manually applied maximal force.[3,5] This intratester reliability data is consistent with values reported in other studies.[12-13]

Ligamentous Testing Description

For all subjects, the uninvolved knee was evaluated first to establish a baseline by which the contralateral knee could be judged. The Lachman tests were performed with the subject lying supine and prone on a firm examination table and the knee flexed to 20-30˚. Care was taken to ensure that both knees were in the same degree of flexion during the physical examination procedures. For the supine examination, the examiner's upper hand stabilized the unsupported distal thigh, while the lower hand, with the thumb on the anterior joint line, and the fingers feeling to ensure that the hamstrings were relaxed, pulled the tibia forward with approximately 30 pounds of force (Figure 1). For the prone

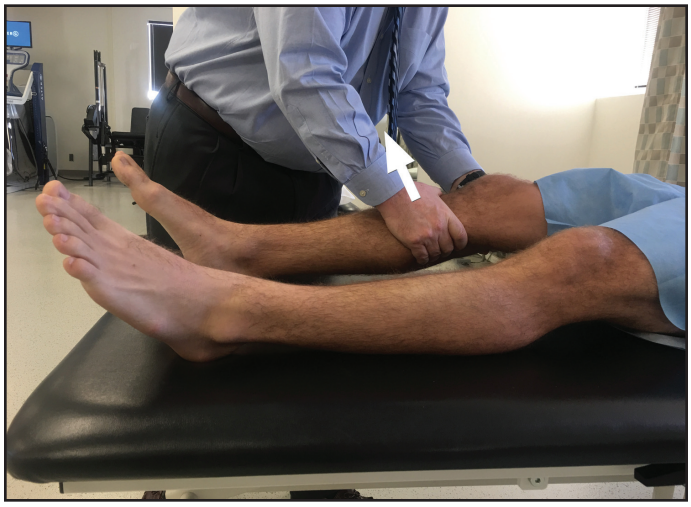

Figure 1. *Supine Lachman Test.*

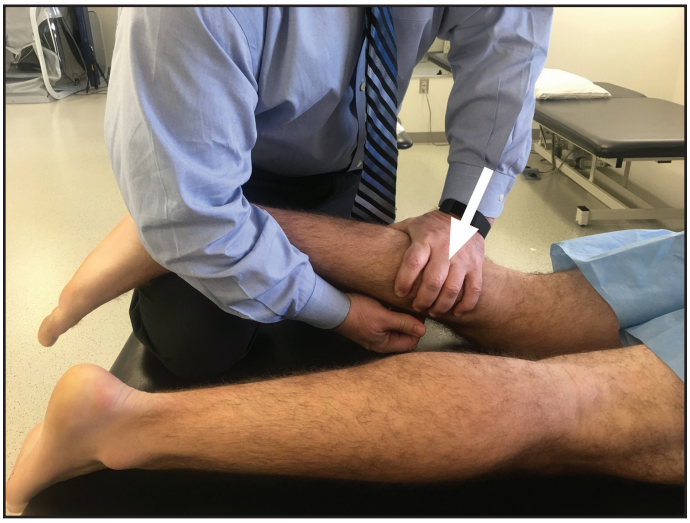

Figure 2. *Prone Lachman Test.*

assessment, the examiner placed the hand closest to the foot (distal hand) on the anterior proximal tibia, with the index and longer finger positioned on each side of the patellar tendon, resting on the anterior joint line. The examiner's thigh was placed under the subject's shin to support the subject in 20-30˚ of knee flexion. The heel of the examiner's other hand (proximal hand) was placed over the posterocentral aspect of the proximal tibia, with the fingers lightly resting on the proximal gastrocnemius muscle belly. The heel of the proximal hand was used to direct an anterior force on the posterior tibia, while the fingers of the distal hand applied slight pressure directed posteriorly and simultaneously palpated the amount of anterior tibial translation relative to the femur (Figure 2).

The examiner judged both Lachman tests as positive or negative based primarily on the presence or absence of a firm end feel. A positive test in either position was based on the absence of a firm end feel with a perception of greater than 3mm more anterior translation on the injured side as compared to the uninvolved side.

The Lever Sign was conducted with the subject supine on an examination table with a rigid transfer board placed underneath the involved extremity during testing. With the examiner positioned alongside the subject, the examiner's distal hand formed a closed fist and was positioned under the proximal third of the tibia. This caused the knee to flex to

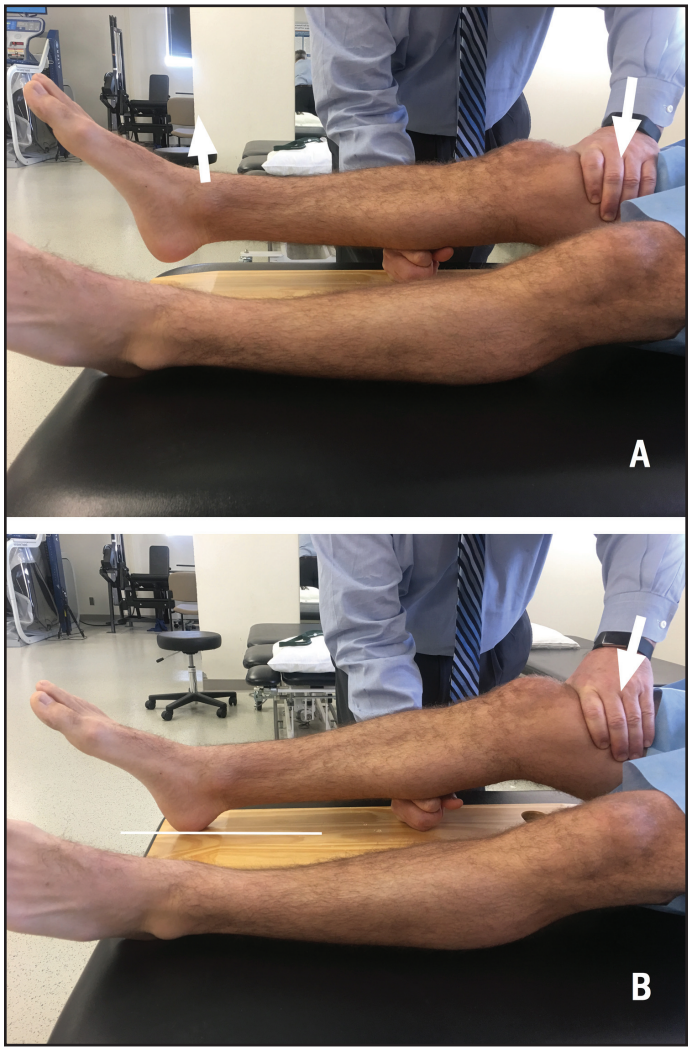

Figure 3. *The Lever Sign. A) Negative Test; B) Positive Test.*

approximately the same amount of flexion as a traditional Lachman test (20-30˚). The proximal hand of the examiner was then free to apply a moderate (30 pounds) downward force to the distal third of the femur. A positive test was present when the posterior force on the thigh did not result in the elevation of the heel from the support surface. Conversely, a negative test was present when the knee extended and the heel rose from the table (Figure 3).[6]

For 19 subjects the gold standard for diagnostic accuracy was direct arthroscopic visualization of the ACL at the time of surgery. Following the assessment of the 41 subjects for whom direct visual evidence through the arthroscope was not available, each subject's ACL status (reference standard) was categorized as intact or torn based on a cluster of clinical findings. To be classified as having a torn ACL, the

subject had to have at least two of the three following findings: 1) a positive MRI; 2) excessive laxity on KT-1000™ examination which was defined as more than 3 mm greater translation on the involved side during the instrumented assessment with the 30 lbs (13.6 kg) and/or manual maximum test as compared to the uninvolved side; and 3) a positive finding on a subsequent independent and comprehensive knee ligamentous evaluation conducted by a physician who was blinded to the original examiner's findings. If less than two of these findings were positive the subject's ACL status was classified as intact.

Fellowship trained sports medicine physicians, orthopedic surgeons, and musculoskeletal radiology investigators not involved in conducting the ACL tests interpreted the MR images and/or evaluated the ACL under arthroscopic visualization. No adverse events were reported for any of the subjects during the index testing or evaluation of the reference standards.

Statistical Analysis

To determine the necessary sample size the authors assumed a minimal sensitivity and specificity of at least 0.95 and a 95% confidence interval with a desired precision width of $\pm$0.10 resulting in the need to enroll a minimum of 48 subjects. A 2x2 contingency table protocol was used to evaluate the sensitivity, specificity, positive and negative predicative values, and likelihood ratios for all special tests. Sensitivity represents the percentage of true positives in all subjects with the reference injury and specificity represents the percentage of true negatives. Consequently, index tests with high sensitivity are thought to be effective at ruling out the presence of the injury while tests with high specificity are effective at ruling in the injury. Positive and negative predictive values reflect the percentage of time that a positive or negative test (respectively) accurately captures the diagnosis. Exact binomial confidence intervals for the positive and negative predictive values were determined by the Clopper-Pearson method through an on-line calculator at http://statpages.org/ctab2x2.html. Positive and negative likelihood ratios reflect changes in the post-test probability when the index test is positive or negative respectively. The confidence intervals for the sensitivity, specificity, and likelihood ratios were computed via an on-line calculator at http://www.pedro.org.au/english/downloads/confidence-interval-calculator/ using the Wilson score method. The number needed to diagnose was derived from the formula 1/[sensitivity – (1/specificity)] and represents the number of tests that need to be performed to gain a positive response for the presence of the injury.

RESULTS

Figure 4 summarizes the flow of the subjects through the study. Twenty-four of the 60 subjects in this study

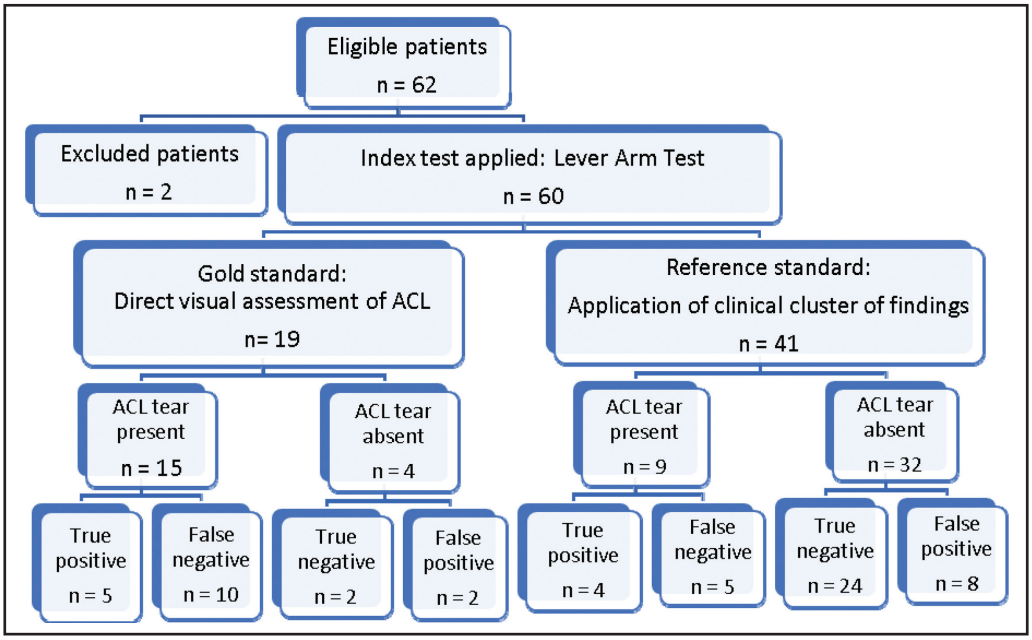

Figure 4. *Flow chart of eligible subjects.*

Table 1. *Demographic Data.*	
Characteristic	
Age [mean years ± SD (range)]	42 ± 13.4 (18-65)
Side of Involvement (frequency)	35 left; 25 right
Sex (frequency)	38 male; 22 female
Mean Days since Injury [mean days ± SD (range)]	55 ± 80 (1-304)
Thigh circumference [(mean cm ± SD (range)]	44.4 ± 5.7 (32.6 - 63.1)
Calf circumference [(mean cm ± SD (range)]	36.8 ± 3.8 (28.5 – 37.1)

had a torn ACL resulting in a prevalence of 40%. The examinations were prospectively conducted on 62 consecutive subjects between September of 2016 and March of 2017; however, only 60 of them were included in the study. One subject was excluded due to a suspected posterior cruciate ligament injury during screening and the other because their pain level and muscular guarding prevented tibial or femoral translation assessment. Demographic information about the subjects is presented in Table 1.

In the gold standard of assessment, group 15 individuals had a torn ACL and four had an intact ACL. For the remaining 41 subjects classified by the reference consensus there were nine individuals with a torn ACL and 32 with an intact ACL.

According to the gold standard index, the sensitivity of the Lever Sign was 0.33 (95% CI 0.23 – 0.44) with a specificity of 0.50 (95% CI (0.10 -0.90). For those subjects where the status of the ACL was determined by reference standard, the sensitivity was 0.44 (95% CI 0.17 0- 0.74) and the specificity was 0.75 (95% CI 0.67 – 0.83). For all subjects combined, the sensitivity was 0.38 (95% CI 0.22 – 0.53) and a specificity of 0.72 (95% CI (0.62 – 0.0.83) with a positive predictive value of 0.47 (95% CI 0.28 – 0.67) and a negative predictive value of 0.63 (95% CI 0.54 – 0.73) (Table 2).

According to the gold standard index, the sensitivity of the Prone Lachman test was 0.81 (95% CI 0.71 – 0.87) with a specificity of 0.67 (95% CI (0.13 – 0.98). For those subjects where the status of the ACL was determined by reference standard, the sensitivity was 0.88 (95% CI 0.53 – 0.99) and the specificity was 0.94 (95% CI 0.86 – 0.97). For all subjects combined, the sensitivity was 0.83 (95% CI 0.68 – 0.93) and a specificity of 0.89 (95% CI (0.78 – 0.0.95) with a positive predictive value of 0.83 (95% CI 0.68 – 0.93) and a negative predictive value of 0.89 (95% CI 0.78 – 0.95). The overall accuracy was of the Prone Lachman test was 87% for all subjects (Table 3).

According to the gold standard index, the sensitivity of the Supine Lachman test was 0.65 (95% CI 0.55 – 0.65) with a specificity of 1.0 (95% CI (0.21 - ¥). For those subjects where the status of the ACL was determined by reference standard, the sensitivity was 0.71 (95% CI 0.35 – 0.85) and the specificity was 0.97 (95% CI 0.90 – 1.0). For all subjects combined, the sensitivity was 0.94 (95% CI 0.73– 1.0) and a specificity of 0.81 (95% CI (0.73 – 0.84) with a positive predictive value of 0.94 (95% CI 0.73 – 0.99) and a negative predictive value of 0.81 (95% CI 0.73 – 0.84). The overall accuracy of the Supine Lachman test was 85% for all subjects (Table 4).

Likelihood ratios for all subjects were computed based on the sensitivity and specificity of each examination technique, yielding a positive likelihood ratio of 1.35 (95% CI 0.57 – 3.07) and a negative likelihood ratio of 0.87 (95% CI 0.57 – 1.27) for the Lever Sign, a positive likelihood ratio of 7.50 (95% CI 3.19 – 19.29) and a negative likelihood ratio of 0.19 (95% CI 0.57 – 1.27) for the Prone Lachman test, and a positive likelihood ratio of 24.0 (95% CI 4.14 – 482.3) and a negative likelihood ratio of 0.34 (95% CI 0.29 – 0.55) for the Supine Lachman test. The

Table 2. *Lever Sign Classification: 2 x 2 contingency table based on gold standard.*

		Condition according to Gold Standard		
		Positive	Negative	Totals
Condition according to Lever Sign Classification	Positive	5	2	7
	Negative	10	2	12
	Totals	15	4	19

Lever Test Classification: 2 x 2 contingency table based on reference standard

		Condition according to Reference Standard		
		Positive	Negative	Totals
Condition according to Lever Sign Classification	Positive	4	8	12
	Negative	5	24	29
	Totals	9	32	41

* To be classified as a torn ACL, the subject had to have at least 2 of the 3 following findings: 1) a positive MRI; 2) excessive laxity (> 3mm on KT-1000™ examination; and 3) a positive finding on subsequent independent and comprehensive knee ligamentous evaluation conducted by a physician

Lever Test Classification: 2 x 2 contingency table for all subjects

		Condition according to Reference or Gold Standard		
		Positive	Negative	Totals
Condition according to Lever Sign Classification	Positive	9	10	19
	Negative	15	26	41
	Totals	24	36	60

diagnostic odds ratio for all subjects was 1.6 (95% CI: 0.45 – 5.40), 40 (95% CI: 7.5 – 254), 70 (95% CI: 7.5 - 1639) for the Lever Sign, Prone, and Supine Lachman tests respectfully.

For all subjects, based on the pretesting prevalence of 40%, the posttest probability from a positive test with the Lever Sign, Prone Lachman, and Supine Lachman tests increased to 48, 84, and 94% and the posttest probability from a negative test reduced the likelihood of an ACL injury to 36, 11, and 18% respectively. The overall accuracy of the examination techniques for the Lever Sign, Prone Lachman, and Supine Lachman test was 58, 87, and 85%, and the number needed to diagnose (NND) was 10.3, 1.4 and 1.6 respectively (Table 5).

DISCUSSION

In a patient presenting with a possible ACL injury, it is important to know the accuracy of the tests used to confirm or refute a diagnosis. Previous studies have established the Lachman and Pivot shift tests to have outstanding specificity but only moderate sensitivity.[1,3-7] One of the compelling qualities regarding the Lever Sign from previous published studies was the improved sensitivity that approached 100% for this examination technique.[6-7] The findings of the

Table 3. *Prone Lachman Test Classification: 2 x 2 contingency table based on gold standard.*

		Condition according to Gold Standard		
		Positive	Negative	Totals
Condition according to Prone Lachman Test Classification	Positive	13	1	14
	Negative	3	2	5
	Totals	16	3	19

Prone Lachman Test Classification: 2 x 2 contingency table based on reference standard

		Condition according to Reference Standard		
		Positive	Negative	Totals
Condition according to Prone Lachman Test Classification	Positive	7	2	9
	Negative	1	31	32
	Totals	8	33	41

* To be classified as a torn ACL, the subject had to have at least 2 of the 3 following findings: 1) a positive MRI; 2) excessive laxity (> 3mm on KT-1000^{TM} examination; and 3) a positive finding on subsequent independent and comprehensive knee ligamentous evaluation conducted by a physician

Prone Lachman Test Classification: 2 x 2 contingency table for all subjects

		Condition according to Reference or Gold Standard		
		Positive	Negative	Totals
Condition according to Prone Lachman Test Classification	Positive	20	4	24
	Negative	4	32	36
	Totals	24	36	60

current study could not replicate this high sensitivity. In fact, the number of false negatives was greater than true positives resulting in an inadequate level of screening for the injury regardless if the index test was compared to a gold or reference standard. Additionally, the specificity was slightly lower with the Lever Sign than the more traditional Lachman examination performed in either the supine or prone positions.

The NND value provides another statistical perspective on the accuracy of the index test. For the Lever Sign test an NND of 10.3 suggests that this test, in isolation, would rarely be adequate to establish the status of the ACL. Conversely, the NNDs of 1.4-1.6 for the Lachman tests suggest that these tests would be accurate for five of every seven to eight subjects on whom the tests would be performed.

The results from this study for Lachman testing were similar to previous investigations in regards to the test's sensitivity and specificity. For the Lachman test performed in supine, pooled data from meta-analyses by Benjaminse et al,[1] Jackson et al,[14]

Table 4. *Supine Lachman Test Classification: 2 x 2 contingency table based on gold standard.*

		Condition according to Gold Standard		
		Positive	Negative	Totals
Condition according to Supine Lachman Test Classification	Positive	11	0	11
	Negative	6	2	8
	Totals	17	2	19

Supine Lachman Test Classification: 2 x 2 contingency table based on reference standard

		Condition according to Reference Standard		
		Positive	Negative	Totals
Condition according to Supine Lachman Test Classification	Positive	5	1	6
	Negative	2	33	35
	Totals	7	34	41

* To be classified as a torn ACL, the subject had to have at least 2 of the 3 following findings: 1) a positive MRI; 2) excessive laxity (> 3mm on KT-1000^{TM} examination; and 3) a positive finding on subsequent independent and comprehensive knee ligamentous evaluation conducted by a physician

Supine Lachman Test Classification: 2 x 2 contingency table for all subjects

		Condition according to Reference or Gold Standard		
		Positive	Negative	Totals
Condition according to Supine Lachman Test Classification	Positive	16	1	17
	Negative	8	35	43
	Totals	24	36	60

and Scholten et al[4] indicate a sensitivity ranging from 0.85 to 0.87 and a specificity ranging from 0.91 to 0.94. In the present study, results for the supine Lachman test showed a similar degree of accuracy with a specificity of 0.97 and a sensitivity of 0.89. The current results were also similar to a previous study of the Lachman test performed in a prone position with almost identical overall accuracy.[5] In the previous study the specificity was slightly better (0.97 vs. 0.89) with a slightly lower sensitivity (0.70 vs. 0.83). The similar results are likely attributable to the same examiner in each study but are similar to other meta-analyses of the accuracy of the Lachman test.

In contrast, this study could not replicate the diagnostic accuracy found in other investigations for the Lever Sign.[6-7] One of the attractive features of the Lever Sign is the simplicity of its interpretation. There should be little debate regarding the rise of the heel. It is possible that the degree of elevation or the force required to impart the lever effect is variable between subjects. Great care was taken to be consistent with the force delivered to minimize this potential confounding variable and properly engage the lever action. It was common to feel an increased posterior translation and/or a soft end feel to this translation during the examination but it this not used to classify the result as positive or negative as it was not

Table 5. *Diagnostic values based Lever Sign, Prone Lachman, and Supine Lachman Tests.*

Diagnostic Parameters	Lever Test	Prone Lachman Test	Supine Lachman Test
Sensitivity (95% CI)	0.38 (0.22 - 0.53)	0.83 (0.68 - 0.93)	0.67 (0.52 - 0.71)
Specificity (95% CI)	0.72 (0.62 - 0.83)	0.89 (0.78 - 0.95)	0.97 (0.87 - 0.99)
Positive Predictive Value (95% CI)	0.47 (0.28 - 0.67)	0.83 (0.68 - 0.93)	0.94 (0.73 - 0.99)
Negative Predictive Value (95% CI)	0.63 (0.54 - 0.73)	0.89 (0.78 - 0.95)	0.81 (0.73 - 0.84)
Positive Likelihood Ratio (95% CI)	1.4 (0.57 - 3.07)	7.5 (3.8 - 17.3)	24.0 (4.1 - 482)
Negative Likelihood Ratio (95% CI)	0.86 (0.57 - 1.27)	0.19 (0.08 - 0.42)	0.34 (0.29 - 0.55)
Diagnostic Odds Ratio (95% CI)	1.6 (0.45 - 5.4)	40 (7.5 - 254.4)	70 (7.5 - 1639)
Number Needed to Diagnose	10.3 (2.79 - (-)6.1)	1.4 (1.1 - 2.2)	1.6 (1.4 - 2.5)

part of the operational definition used in the founding investigations. Many previous studies have demonstrated the importance of considering the "endpoint" in establishing the integrity of the ACL.[5,15-18] Inclusion of this criterion in future studies may help improve the accuracy of this diagnostic test.

In the four cases in which all three examination procedures resulted in a false negative for a torn ACL there were no consistent demographic or concurrent injuries to explain the error. In two cases the subjects were older (50 and 53 years of age) than the mean study population, one had arthrofibrotic changes following an ACL reconstruction that mandated a manipulation under anaesthesia eight years previously, and the remaining subject had suffered an ACL graft re-tear approximately nine months previous to the examination. The examiner differed in his interpretation of the Lachman test in prone and supine positions in six cases. In five of these six cases, the prone examination correctly detected the ACL. Conversely, in one instance, the examiner incorrectly categorized the subject as an ACL tear based on the prone examination while the supine examination was correctly interpreted as negative for a torn ACL. There were no consistent demographic or concurrent injuries to explain these phenomena.

The pivot shift test was intentionally not included in this study due to its known lack of sensitivity and the fact that all current evaluation techniques (Lachman and Anterior Drawer tests) have displayed a similar high level of specificity.[1,3-4] Additionally, the pivot shift test is an assessment of rotational stability while the Lachman, Anterior Drawer, and Lever Sign are all assessments of translational stability. As with previous investigations this investigation did not evaluate the reliability of the Lever Sign. It was assumed the ease of test interpretation would minimize the need for examiner expertise to categorize the test finding. In retrospect, reliability should be evaluated between examiners to ensure that consistent force levels are applied and if there could be agreement, beyond chance, regarding the endpoint of the posterior femoral translation.

The rationale for the current study sample size was powered by previous research that indicated a high degree of accuracy.[6-7] Retrospectively, the relatively wide diagnostic accuracy confidence intervals that were reported may have suggested that an even larger sample size to improve the measurement precision of point estimates regarding the diagnostic truthfulness for the Lever Sign. Another acknowledged shortcoming of this study is that 41 of the 60 patients were classified without the benefit of direct, intraoperative visual assessment of the status of the ACL and had to be assigned to a category based on a cluster of clinical impressions and signs. While this

classification is less than optimal, the authors are confident that the clinical consensus formula based on the subsequent results of MRI findings, orthopaedic surgeon evaluation, and joint arthrometry dichotomized each patient into the category that truly represented the status of the ACL. Of the 19 patients in whom there was direct visual evidence of the ACL through arthroscopy, the clinical cluster accurately identified those patients who had an ACL tear (n = 15) and those who did not (n = 4).

The strength of this study design is that it reduces both selection and verification bias as there was an intentional inclusion of a wide range of musculoskeletal knee disorders. The authors are confident that the study cohort represents a wide, age-appropriate spectrum of patients with both acute and chronic knee pathology severity.

CONCLUSION

The results of this study indicate that Lever Sign, in isolation, does not accurately detect the status of the ACL. During the clinical examination, the Lever Sign should be used as an adjunct to the gold standard assessment technique of a Lachman test in either prone or supine positions. Further study of the Lever Sign in a larger patient population of patients with knee pain complaints is recommended with additional consideration for how, or if the endpoint assessment to posterior femoral translation adds value to the diagnostic decision.

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